[0043] Shear sensors have two disadvantages in cold climates. In particularly cold climates, it is important for touchscreens to sense touches of fingers of gloved hands. Shear waves have reduced sensitivity compared to Rayleigh waves thus making detection of gloved fingers more difficult. Secondly, in such climates, drops of water may freeze to form solid ice. While liquid water does not strongly couple to horizontally polarized shear waves, ice does. Thus drops of water which freeze on the touchscreen surface will cause shadowing or blinding.

[0044] There remains a need for a touch position sensor which operates reliably in the increasingly rugged environments to which such devices are deployed. There thus exists a need to supplement existing technologies in order to extend the applicability of acoustic touch sensor systems.

[0045] g. Size Constraints.

[0046] Acoustic sensors of the Adler type have been considered for use in electronic white boards; see **FIG. 10** and associated text in E.P. Application 94119257.7, Seiko Epson. At present, no commercial electronic whiteboard products are available based on acoustic sensors technology. In part, this is because of size limitations for known acoustic technology.

SUMMARY OF THE INVENTION

[0047] The present invention derives from an understanding that acoustic position measurement technology suffers from various limitations, which may be addressed by implementing a system with various forms of partial redundancy in the sensing waves. Thus, for each coordinate axis of the output, a plurality of sets of waves are provided bearing information about the position of a single touch along that axis. Therefore, any limitation in the ability of one set of waves to determine a touch position may be supplemented by information derived from at least one other set of waves. Because the redundancy may be partial, other information may be derived from the available sets of waves as well, including a characteristic of a touch and information relating to a plurality of touches.

[0048] According to one set of schemes for producing partially redundant sets of waves, a plurality of sets of waves are provided, each propagating at a different angle with respect to the axis along which a touch position is to be sensed. Each of the waves should be able to sense position along a significant portion of the axis. Thus, a traditional type touch system provides two sets of waves which are each parallel to an edge of a rectangular substrate and produce waves which propagate perpendicular to the edges. Thus, each set of waves is dedicated sensing a position along a particular axis. Likewise, a known bisected reflective array scheme overlaps waves over an insignificant portion of the touch sensitive surface, and the waves generated are of the same frequency, mode, axis of propagation and therefore are essentially fully redundant and likely bear essentially the same information.

[0049] The present invention also extends these same principles to encompass a number of other embodiments, including acoustic touch systems in which the acoustic waves travel along paths which are neither parallel nor perpendicular to an edge of a substrate or travel along a path which is neither parallel nor perpendicular to a reflective array. Thus, the present invention relaxes constraints imposed in prior touch position sensors through an understanding that the geometry of the touch sensor substrate, reflective arrays or acoustic paths need not limit the coordinate system represented in an output. Thus, the present invention may provide control systems which are capable of performing coordinate system transforms and higher levels of analysis of the information contained in the acoustic signals than prior systems.

[0050] In forming this understanding that a control need not be limited to a conversion of a characteristic timing of a perturbation of an acoustic wave into a coordinate position along a single axis, the possibility of non-Euclidean geometric shapes is developed. Thus, while the prior art teaches that acoustic touch sensing may be applied to spherical portions of CRT faceplates, the goal of the prior art was to provide a system in which analysis of the received acoustic signals were as if the substrate were planar. Therefore, those prior art systems were developed to compensate for the spherical aberrations in the design and placement of the reflective arrays. Likewise, a known prior art system employs a diverging set of waves incident on a reflective array to sense a unidirectional angular measurement. In this case, a control treats the unidimensional angular measurement as a single coordinate axis without transformation.

[0051] The present invention provides touch system flexibility allowing analysis of waves which propagate along non-orthogonal axes in the touch sensitive region of the touchscreen. Further, the present invention provides a touchscreen system which tolerates and analyzes waves which are overlapping in time, i.e., simultaneously impinging on one or more receiving transducers. Together, these related aspects of the invention provide greatly enhanced flexibility in the design of the touchscreen, with improved performance under adverse conditions.

[0052] The present invention also includes touch sensors for purposes other than graphic user interfaces. For example, applications in the field of robotics exist, in which it is desirable to endow robots with a sense of touch. While a number of sensor technologies exist, acoustic sensing provides an opportunity for a large area, high resolution, low cost per unit area sensor on a machine, for example, to detect contact or pressure with an adjacent object and to determine the location of the touch. Such machines often have non-planar surfaces, and as such it is advantageous to provide a touch position and/or pressure sensor which conforms to the shell of the machine. According to the present invention, various surfaces having irregular geometries may be formed into sensor surfaces.

[0053] The present invention also provides a touch system allowing analysis of a wave perturbation of two different types of waves, the waves differing in mode, frequency, waveform, velocity, and/or wavelength. This system advantageously allows redundant position measurement and/or differential wave perturbation sensing.

[0054] One aspect of the invention can also be described as follows. Acoustic energy is emitted into a substrate supporting propagation of acoustic waves. This energy travels through a portion of the substrate to a receiving system, which may include redundant use of the acoustic energy emitting device. The energy is received as at least two distinct waves. These waves have differing paths or charac-